Sensitivity of Western and Northern Canada Surface Waters To Acidic Inputs

Prepared by:

Coordinating Committee on Surface Waters

For:

Western and Northern Canada LRTAP Technical Committee

December 1987

ACID RAIN

PLUIES ACIDES

BC Ministry of Environment

Alberta ENVIRONMENT

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Northwest Territories Renewable Resources

Canada

SENSITIVITY OF WESTERN AND NORTHERN CANADA

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ABSTRACT

An overview of the sensitivity of lakes in western and northern Canada to acidic deposition is presented, based upon criteria developed for alkalinity and calcium by the Coordinating Committee on Surface Waters for the Technical Committee for the Long Range Transport of Air Pollutants in Western and Northern Canada. Highly sensitive lakes are defined by the criteria as having an alkalinity value of less than 10 milligrams per litre (mg/L) or a calcium value of less than 4 mg/L. Moderately sensitive lakes are defined as having an alkalinity value between 10 and 20 mg/L, or a calcium value between 4 and 8 mg/L. The lower of the median calcium or median alkalinity value is used to determine a lake's sensitivity classification. Using these criteria, it was determined that generally, lakes in the Northwest Territories, in the Precambrian Shield area of northern Saskatchewan, and along the west coast of British Columbia are classified as being highly sensitive. Based on the extrapolation of Saskatchewan and Northwest Territories data, the northwest region of Manitoba is most likely highly sensitive, as well. Except for numerous small areas that are moderately sensitive, the rest of the region has a low sensitivity to acidic inputs.

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1.0 INTRODUCTION

1.1 What is Sensitivity?

Sensitivity is an interpretation of information about environmental components or receptors, which rates their likely response to acidic inputs. In this report, it refers to interpretations which describe the response of surface waters in western and northern Canada.

In April, 1981, the technical committee on Western Canada Long Range Transport of Atmospheric Pollutants noted the need for a co-ordinated program across the four western provinces and the Northwest Territories (NWT) to map the sensitivity of surface waters to acidic deposition. This would be consistent with similar studies already completed for Ontario, Quebec, and the Maritime provinces.

The primary objective of this report is to present an overview of the sensitivity of lakes in western and northern Canada to acidic deposition.

1.2 What are Sensitivity Maps?

Parameters which describe the buffering capacity of surface waters are chosen and criteria selected to establish sensitivity rating classes. Once the sensitivity classes have been established, maps can be prepared showing the extent and distribution of each sensitivity class.

1.3 Why Produce Sensitivity Maps?

Development of sensitivity maps for the provinces and territories of Western Canada has been a priority task of the Acid Rain and Long Range Transport of Air Pollutants (LRTAP) program. Several objectives for this mapping can be stated. First, they show locations and extent of sensitive areas, for comparison with acid deposition information to identify control areas. Second, sensitivity mapping affords an opportunity to review and compile surface water information useful to assessing degradation, and provides a framework for possible further site specific and more detailed investigations of response to acidic inputs.

1.4 Role of the Co-ordinating Committee on Surface Waters Sensitivity Mapping

The Co-ordinating Committee was formed in 1981 to: provide information on the status of sensitivity mapping in each area of jurisdiction, identify available information for a mapping program, establish sensitivity rating criteria for the appropriate parameters, select the data base, choose the mapping scale and co-ordinate the mapping activity to ensure reasonable consistency among the provinces and territories.

1.5 Maps Prepared as Part of this Project

Each province and the territories prepared sensitivity maps, at a scale of 1:2,000,000, of pH values, calcium values, and alkalinity values. An additional map was also produced which combined the calcium and alkalinity sensitivity maps. The highest sensitivity rating for either of the two maps was used to determine an area's sensitivity rating on the combined map.

Accompanying this report are four generalized and smaller scale maps (1:7,500,000) which combine the maps prepared by the provinces/territories for each of the parameters described earlier.

Sensitivity mapping based on surface water data, soils data, surficial geological data or any other data is simply a planning tool at a macroscopic level. The sensitivity interpretations and resultant maps for western and northern Canada are a first effort.

2.0 SENSITIVITY RATING CRITERIA

2.1 Background

In April, 1981, the Western Canada Long Range Transport of Atmospheric Pollutants Technical Committee noted a need for a co-ordinated program across the four western provinces and the Northwest Territories, to map the sensitivity of soils, geology and surface waters to acidic deposition. This was consistent with similar studies already completed for Ontario, Quebec and the Maritime provinces by the National Research Council of Canada (NRCC) Associate Committee on Scientific Criteria for Environmental Quality (1981). As well, the Saskatchewan Research Council (Shewchuk et al., 1981) had rated and mapped a portion of northeastern Alberta and northern Saskatchewan. No other sensitivity mapping had been undertaken in western and northern Canada. Therefore, a Co-

ordinating Committee on Surface Waters was established to investigate data bases and criteria for co-ordinated mapping of surface waters in western and northern Canada. (Saskatchewan Research Council, 1982).

2.2 Factors Important to Sensitivity Rating

Parameters had to be determined to describe surface water sensitivity common to water quality measurements in several areas of jurisdiction, relatively free of potential error due to sampling and analytical techniques, while at the same time providing some scientific basis for sensitivity evaluation (Saskatchewan Research Council, 1982). Five parameters were evaluated from among those used in similar mapping studies undertaken in eastern Canada (NRCC, 1981) and in Saskatchewan (Liaw and Atton, 1981) thereby providing some continuity with these earlier studies. These are described briefly below; a more in-depth description is found in the Saskatchewan Research Council report (1982).

pH - Provides the most direct measurement of acidification of surface waters but is not an indicator of sensitivity. It is one of the most

easily measured water quality parameters, and has been most consistently measured over the longest period of time.

Alkalinity - Carbonate-bicarbonate buffering capacity of a waterbody determines, to a significant degree, the extent to which neutralization of acidic inputs will occur, thereby providing a most direct measure of sensitivity to acidification. The following sensitivity criteria (Saskatchewan Research Council, 1982) were used for mapping:

Sensitivity	Alkalinity (mg/L $CaCO_3$)
Highly sensitive	0-10
Moderately sensitive	10-20
Least sensitive	>20

Because of the limitations of methodologies employed for many of the alkalinity measurements this analysis is not exact but does indicate broad sensitivity regimes (NRCC, 1981).

Calcium and Magnesium - Carbonate and bicarbonate anions acting as the main buffering agents in surface waters are most generally balanced by calcium and magnesium cations. Calcium alone or together with magnesium can therefore be used as a

good indicator of buffering capacity and sensitivity of lakes to acidification. The following criteria for sensitivity rating based on calcium were proposed (Saskatchewan Research Council, 1982).

Sensitivity	Ca (mg/L)
Highly sensitive	0-4
Moderately sensitive	4-8
Least sensitive	>8

The calcium and magnesium data could further be used to draw relationships between alkalinity and $Ca^{++} + Mg^{++}$ or pH and Ca^{++}. A plot of pH vs Ca^{++} provides a curve which could be used as a basis for separating acidic from non acidic lakes (Henriksen, 1979; from NRCC, 1981).

Aluminum - This metal was considered but was deemed to not be appropriate for sensitivity mapping.

Each agency was asked to undertake a search of existing water quality data to determine the numbers of lakes for which at least one measurement was available for each of the above parameters. The data base assembled included for the most part, freshwater lakes only. The sensitivity mapping

program for eastern Canada showed that where terrain is homogeneous, river data could be used to represent the sensitivity of the entire watershed, as in Quebec. However, where terrain is too heterogeneous with respect to buffering capacity, river water quality is no longer a useful index of buffering capacity for the entire basin (eg. Ontario). In dealing with as large and geologically heterogeneous an area as western Canada with large river drainages which dissect a variety of formations, it was assumed that lake data would be more appropriate for the mapping program.

2.3 Sensitivity Rating Criteria

On the basis of data available, preliminary sensitivity mapping in each province and territory proceeded according to the following criteria:

- Sensitivity maps using alkalinity and calcium data were prepared to outline the buffering capacity of surface waters and thereby the sensitivity to acidification to complement similar mapping programs undertaken elsewhere in Canada.
- Sensitivity ratings outlined in section 2.2 were used to ensure continuity with studies already completed.

- Maps using pH were prepared to determine the state of acidification to date.
- In recognition of the potentially severe limitations of these data, only data since 1973 were used.
- Numerous data were available for rivers and streams in addition to the lake data provided. In areas where appropriate coverage was not derived from lake data, stream data were used with discretion.
- The majority of data points were represented by only one measurement. For those with more than one measurement the median of the available pH, alkalinity and calcium value was calculated for any point or group of sampling stations in a lake.
- A map scale of 1:2,000,000 was used to allow reasonably accurate identification of sampling sites and to provide a degree of accuracy consistent with the quality of the available data base.
- Regional maps were then prepared at a scale of 1:7,500,000 and accompany this report.

3.0 MAPPING METHODOLOGY

3.1 British Columbia

The British Columbia Ministry of Environment

prepared its first lake sensitivity maps based upon data collected by Ministry staff and analyzed at the Ministry laboratory. This provided a consistent data base. The maps were based on data collected from 1977 to 1981 (181 lakes with calcium data and 158 lakes with alkalinity data) and stored on the Ministry's computerized storage system.

Newer maps incorporating data collected in 1982 and 1983 (542 lakes with calcium data and 519 lake with alkalinity and pH data) were completed in 1984. The data collected after 1981 were collected by three methods. One was to use fixed-wing aircraft to fly to lakes in areas with no data. The second was to have Ministry staff collect data near roads which they may pass on their travels. The third method was to have a group which prepare bathymetric maps around the province collect samples on those lakes.

The sensitivity maps were prepared on the basis of contour interval mapping techniques, with no attention being paid to watershed boundaries. Consideration was given to mapping according to watershed boundaries; however, even more data than presently are available would be required. The

contour interval mapping technique was used in British Columbia for several reasons. These are: the mapping of lakes takes into account the fact that watersheds are heterogeneous; random sampling techniques have been employed to collect data, resulting in the possibility that some watersheds have not been sampled; geological formations in adjacent areas of watersheds bordering each other are likely similar; and precipitation does not fall according to watershed boundaries but more according to the location of mountain ranges.

3.2 Alberta

The collection of data in Alberta occurred in two phases. Phase One included the compilation of existing water quality data (1973-1985) for 875 lakes. (Erickson, 1985). Only data collected during the open water period of May 1 to October 31 of each year were included in the analysis.

Phase Two consisted of a preliminary lake sampling program undertaken to augment existing data or data derived from single samples and to provide data for areas in the province which had not been sampled. One hundred and seven (107) lakes were sampled between August 29, 1983 and October 26, 1983 from a

float-equipped De Havilland Beaver aircraft. Profiles of physical variables were measured at the deepest part of each lake (determined through hydrographic maps).

Depth-integrated-samples were collected, using weighted Tygon tubing, from five widespread areas of each lake. Sample containers and Tygon tubing were triple rinsed with sample water. Samples were taken within the epilimnetic zone (in stratified lakes) or euphotic zone (in unstratified lakes). In shallow lakes (less than 2 metres maximum depth) where the euphotic zone extended to the bottom, samples were collected to within 0.5-1.0 metres of the sediment. Routine chemical analyses were conducted by the Alberta Environmental Centre at Vegreville.

Although 982 lakes were sampled, not all parameters were measured in all the lakes. Alkalinity was measured at 889 lakes, calcium at 921 lakes and pH at 960 lakes.

Upon completion of field work and compilation of historical data, all data were tabulated and summarized. Where multiple values for a variable

were available for a lake, means were calculated to obtain one point for mapping purposes. A network of Thiesson or Vorcni polygons (Monmonier 1984), partitioning the region into proximal neighbourhoods around each lake, was established to delineate boundaries of the sensitivity areas.

3.3 Saskatchewan

The data for Saskatchewan were collected in two phases. Phase One included the compilation of existing water quality (1977 to 1982) data for 260 Saskatchewan lakes. The data were obtained from existing Saskatchewan Environment water quality files, Parks and Renewable Resources fisheries files and from data collected for environmental impact baseline studies. (L. Lechner, et al 1987)

Phase Two consisted of a lake sampling program undertaken to augment existing data and to infill areas which had not been sampled in the past. One hundred and sixty one (161) lakes were sampled between June 1983 and October 1985. Samples were collected near the water surface (0.3 metres) at the deepest point of the lakes.

Although 420 lakes were sampled, not all the parameters were measured in all the lakes. Alkalinity was measured at 420 lakes, calcium at 320 lakes and pH at 420 lakes.

Upon completion of field work and compilation of historical data, all data were tabulated and summarized. Using these data, Environment Canada prepared initial contour maps. Lines representing the appropriate contour intervals were plotted on maps with the aid of the General Purpose Contouring Program (GPCP) operating on the CYBER Computer at the Federal Department of Energy, Mines and Resources, Computer Science Centre. (GPCP Users' Guide, 1979). The contours were then adjusted manually to remove any anomalies in the computer based maps. It should be noted that the contours were not plotted on a watershed basis. Such a delineation would have been too detailed for the map scale chosen (1:2,000,000) and also would have been inconsistent with work carried out in eastern Canada.

3.4 Manitoba

Water quality data were collected from a variety of sources. Data were obtained from Manitoba

Environment and Workplace Safety and Health, Natural Resources, Freshwater Institute, Universities, federal agencies and from a literature search of Manitoba publications. In addition, the Canada-Manitoba Regional Lake Sediment and Water Geochemical Reconnaissance Program provided the majority of the data. These data were collected in a small region of the mid northwest. Virtually no data have been collected in the northern third of the province. Data from a total 6,293 lakes were collected. This is approximately 11% of the total number of Manitoba lakes (Green, 1984).

Once the data were tabulated and summarized, Environment Canada prepared initial contour maps. Lines representing the appropriate contour intervals were plotted on maps with the aid of the General Purpose Contouring Program as explained in Section 3.3. The contours were adjusted manually to remove any anomalies in the maps.

3.5 Northwest Territories (NWT)

The primary data source for the NWT was the National Water Quality Data Base (NAQUADAT) maintained by Environment Canada. A copy of all

available NWT data for the period 1973 to 1983 was obtained and screened with respect to appropriateness for aquatic sensitivity mapping. The NAQUADAT data base was supplemented with data from research reports, studies, and environmental impact assessments conducted by a variety of government and non-government agencies.

Although there were 571 sampling sites, not all of the sites were sampled for each of the three mapped parameters. Alkalinity was measured at 420 sites, calcium at 459 sites, and pH at 510 sites.

It must also be noted that many of the stations, although having a unique latitude and longitude, occur in clusters, with the result being that wide geographic areas are sparsely represented.

June, July and August were the months in which most of the samples were collected, although all of the months of the year were represented at least once.

The aquatic sensitivity maps for the NWT were completed with the aid of the General Purpose Contouring Program (GPCP) operating on the CYBER computer, at the Computer Science Centre,

Department of Energy, Mines and Resources, in Ottawa. The procedure described is largely taken from the GPCP User's Guide (1979). The contours were then adjusted manually to remove any anomalies in the computer based maps.

4.0 GENERAL OBSERVATIONS ON SENSITIVITY MAPS

Sensitivity maps based on calcium, alkalinity, and combined calcium and alkalinity concentrations are found in the envelope located on the inside of the back cover of this report. A map showing present lake acidity (pH contours) is also included.

4.1 British Columbia

The accompanying sensitivity maps show that lakes within about 250 kilometres from the west coast, on Vancouver Island and the Queen Charlotte Islands, and in several other scattered but considerably smaller areas are categorized as moderately to highly sensitive to acidic inputs. These scattered areas are near Atlin Lake in the north west corner of the province, north of Stuart Lake in the centre of the province, and north of Shuswap Lake in the south east. The remainder of the province is considered to be of low sensitivity.

4.2 Alberta

The alkalinity sensitivity map shows that lakes found in the Birch Mountains area of the Fort McMurray region and most of the lakes in the Caribou Mountains region are categorized as moderately to highly sensitive. Large areas containing sensitive lakes were also found in the Jasper National Park region and in the Canadian Shield region. Small numbers of sensitive lakes occur, though rather infrequently, around Lesser Slave Lake in the Swan Hills region, and within Waterton National Park.

Areas containing lakes that were moderately to highly sensitive based on calcium values included all of the Caribou Mountains region, sections of the Birch Mountain and Muskeg Mountain Uplands in the Fort McMurray region, and the Canadian Shield region around Lake Athabasca. Localized areas that can be considered highly sensitive to acidification were found in the Grande Prairie and Swan Hills region and in the Jasper and Waterton National Parks regions.

4.3 Saskatchewan

The maps show that lakes within the Precambrian

Shield region are highly sensitive to acidic inputs. Lakes in a narrow band along the southern boundary of the Precambrian Shield are categorized as moderately sensitive. The remainder of the province is well buffered and lakes in this area have a low sensitivity to acidic inputs.

4.4 Manitoba

In Manitoba the maps identify the area east of Lake Winnipeg as moderately sensitive to acidic inputs and a small area east of Reindeer Lake in the mid northwest of the province as highly sensitive. Virtually no data are available for the northern region of the province. However, looking at the classification of the area in Saskatchewan and the Northwest Territories adjacent to the Manitoba border, it can be assumed that northern Manitoba would also be rated as highly sensitive. The remainder of the province is rated as having a low sensitivity to acid rain.

4.5 Northwest Territories

The aquatic sensitivity maps show a clear east-west division roughly following the Precambrian Shield line south from Great Bear to Great Slave Lake. The area east of this line (Precambrian Shield) is

categorized as highly sensitive. A rapid decrease in sensitivity occurs to the west from the sensitive bedrock and soils of the shield area. The sensitivity map based on calcium values also shows moderate sensitivity along the northern coastline.

5.0 LIMITATIONS OF MAP USE

Sensitivity mapping, based on lake data, soils data, surficial data or any other data is simply a planning tool at a macroscopic level. The lake sensitivity interpretations and resultant maps for western and northern Canada accompanying this report are a first effort. The data base used to prepare the maps was quite sparse. Quite often the data were clustered in some regions while other areas were quite poorly represented, with only single data points. Specific regions have also been identified where no data have been collected. Consequently, the contours drawn on these maps are general trends.

These maps, along with other factors, can be used to make decisions on preliminary siting of industrial operations. However, the maps are not

meant to replace site-specific assessments once one or several preliminary sites have been selected.

6.0 SUMMARY

The lake sensitivity maps show that the major highly sensitive areas in western and northern Canada are located in the Northwest Territories, northern Saskatchewan and along the west coast of British Columbia and Vancouver Island.

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